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The Perceived Urgency of Tactile Patterns During Dismounted Soldier Movements

by Timothy L. White and Andrea S. Krausman

ARL-TR-6013 May 2012

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ARL-TR-6013 **May 2012**

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Timothy L. White and Andrea S. Krausman
Human Research and Engineering Directorate, ARL

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
May 2012	Final	

4. TITLE AND SUBTITLE	
The Perceived Urgency of Tactile Patterns During Dismounted Soldier Movements	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Timothy L. White and Andrea S. Krausman	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: RDRL-HRS-B Aberdeen Proving Ground, MD 21005-5425	**8. PERFORMING ORGANIZATION REPORT NUMBER** ARL-TR-6013
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This research examines the effects of stimulus intensity and inter-stimulus interval (ISI) on Soldier ratings of signal perceived urgency and Soldier detection and identification of tactile patterns while performing dismounted maneuvers. A tactile system including an adjustable belt developed by Engineering Acoustics, Inc. (EAI), provided the tactile stimuli. This adjustable belt, which consists of eight EAI C2 tactors positioned at 45° intervals, was worn around each participant's waist. Participants received tactile patterns at an intensity of either 12.0 or 23.5 dB above mean threshold with an ISI of either 0 (no interval) or 500 ms. Participants were asked to identify each tactile pattern that they received and rate how urgent they perceived the pattern to be on a scale of 1 to 10, where 1 was least urgent and 10 was most urgent. Patterns presented at the 23.5 dB intensity with no ISI were rated most urgent, but at the 12.0 dB intensity, there was no difference in ratings of perceived urgency based on ISI. Patterns presented at the stronger 23.5 dB intensity had significantly greater detection and identification rates than those presented at the 12.0 dB intensity. Findings indicate that it is possible to add urgency to tactile patterns in dismounted environments.

15. SUBJECT TERMS

tactile displays, dismounted maneuvers, tactile patterns, perceived urgency

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Timothy L. White
Unclassified	Unclassified	Unclassified	UU	53	19b. TELEPHONE NUMBER (*Include area code*) 410-278-5933

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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Acknowledgments

We would like to express our appreciation to the following individuals who assisted in the conduct of this research:

- Sergeant Major Christopher Harris and Command Sergeant Major Tydious McCray for their assistance in obtaining volunteers for this study
- Asisat Animashaun, Micheala McBride, Rodger Pettitt, and Rhoda Wilson for their assistance with data collection

Last, but never least, we would like to thank the Soldier participants from the 3rd Heavy Brigade Combat Team/3rd Infantry Division at Fort Benning, GA, for their enthusiasm and dedication to this project.

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1. Introduction

In recent years, there has been an increased interest in tactile displays because of the need to provide complex information to users who are subject to visual and auditory overload and due to the development of more sophisticated tactile display technologies (Jones and Sarter, 2008). Much of the information that Soldiers are currently being provided is presented visually and auditorily. Furthermore, as future technologies advance, Soldiers will be provided with even more information regarding combat situations. The multiple-resource theory suggests that offloading information from overtaxed sensory modalities to other modalities can reduce workload (Wickens, 2002). Tactile displays may be a viable solution to help mitigate the overload and performance degradation that can result from this abundance of information being provided to Soldiers. If designed and implemented properly, tactile displays may improve Soldiers' situation awareness and survivability on the battlefield.

A number of research efforts have already shown the potential of tactile display systems in military environments. Research efforts to employ tactile displays for orientation, navigation, and communication are ever increasing (van Erp and Self, 2008). Some researchers are interested in the use of tactile patterns to communicate more complex messages. For example, Brewster and Brown (2004) addressed some basic approaches to developing "Tactons" or tactile icons to communicate messages. In one study that compared conventional Army hand and arm signals to hand signals coded as tactile patterns, Soldiers were able to receive, interpret, and accurately respond to the tactile patterns faster than with the hand and arm signals while negotiating an obstacle course (Pettitt, Redden, and Carstens, 2006). In another investigation, participants were able to identify and navigate using tactile patterns (e.g., left, right, turn around, move forward) with almost perfect accuracy (Jones, Lockyer, and Piateski, 2006). In an extension of the work of Jones et al., 2006, Krausman and White (2006) found that tactile pattern detection and identification rates were degraded while negotiating obstacles. A noteworthy difference in the Pettitt investigation and the other two mentioned investigations is the type of tactile system used. The Pettitt investigation employed an acoustic transducer in which the intensity was higher than the pancake motors used in the other two investigations.

Parameters such as frequency, amplitude, and duration of tactile signals have been used to encode tactile patterns (Brewster and Brown, 2004). In military environments, some signals or messages may need to be encoded with some level of urgency. Research has shown that varying the parameters of auditory signals can be used to provide humans with a sense of urgency. In one study, signals with shorter inter-pulse intervals and higher sound pressure levels were rated as more urgent (Haas and Edworthy, 1996). Similarly, varying inter-stimulus intervals in tactile patterns may also be a possible method of displaying urgency. The findings of another study that employed "Tactons" that were created from a combination of spatial location, rhythm, and

roughness suggest that varying tactor intensity may also be a feasible alternative of displaying urgency (Brown, Brewster, and Purchase, 2004). In another laboratory study, results showed that the manipulation of inter-stimulus interval and intensity are a feasible means of adding a sense of urgency to tactile patterns (White, 2011).

Interruption management is key to the successful use of tactile patterns with some level of urgency. A number of investigations have been conducted in this area. In one study, researchers found that tactile cues may be useful in directing attention when multiple tasks are being performed (Hopp et al., 2005). Smith et al. (2009) found that tactile cues yielded consistently high attendance rates to interruptions in an interruption management study that compared auditory to tactile cues. Although tactile cues have shown potential in directing attention to secondary tasks, careful consideration should be given to the implementation of tactile cueing during concurrent tasks (Ferris, Hameed, and Sarter, 2009).

2. Hypotheses

A laboratory study was conducted to examine the effect of tactile signal intensity and inter-stimulus urgency coding on dismounted Soldier performance. This investigation was conducted to examine how performance is affected when used during dismounted movements. Although intensity and inter-stimulus interval have been successfully used to distinguish the urgency of tactile signals in a laboratory setting (White, 2011), it was not known how the varying intensities and inter-stimulus intervals will interact with each other in dismounted environments. Based on what was found in the White (2011) study, it was hypothesized that tactile patterns provided at the 12.0 dB intensity would be more difficult to detect and identify than those presented at 23.5 dB. Researchers have found that weak tactile signals may go unnoticed (Gilson, Redden, and Elliott, 2007). White (2011) found that tactile patterns provided with a 0 ms inter-stimulus interval and 23.5 dB intensity were rated the most urgent while those with a 500 ms inter-stimulus interval and 12.0 dB intensity were rated the least urgent. Similarly, it was hypothesized that the tactile patterns that have a 0 ms inter-stimulus interval and 23.5 dB intensity would be rated the most urgent, and that patterns with a 500 ms inter-stimulus interval and 12.0 dB intensity would be rated the least urgent.

3. Objective

The objective of this investigation was to determine the effects of inter-stimulus interval and stimulus intensity on perceived urgency and the detection and identification of tactile patterns by Soldiers performing dismounted maneuvers. During the study, the Soldier participants verbally

identified tactile patterns, and then indicated their perceived urgency level under various levels of stimulus intensity and inter-stimulus duration. Participants were asked to rate which inter-stimulus interval and stimulus intensity combination they perceived to be most and least urgent. The results of this research will provide further insight on how to effectively employ tactile patterns as a means of communicating information to Soldiers.

4. Method

4.1 Participants

Twenty-two male Soldiers from the 3rd Heavy Brigade Combat Team/3rd Infantry Division at Ft. Benning, GA, volunteered to participate in this research. The participants ranged in age from 18 to 29 years of age (mean = 22.4 years; standard deviation [SD] = 2.8 years) with 0.7 to 5.6 (mean = 2.9 years; SD = 1.3 years) years of time in service. Eleven of the twenty-two participants had combat experience in either Iraq or Afghanistan.

The voluntary, fully informed consent of the persons used in this research was obtained as required by 32 Code of Federal Regulations (CFR) 219 and Army Regulation (AR) 70-25 (1990). The investigators adhered to the policies for the protection of human subjects as prescribed in AR 70-25.

4.2 Apparatus

4.2.1 Tactile System

An Engineering Acoustics, Inc. (EAI) C2 tactile system was used, which consisted of an adjustable tactile belt display (figure 1) worn around the waist and a receiver unit. The adjustable belt display consisted of eight EAI C2 tactors (acoustic transducers) approximately 3.048 cm in diameter. A belt display was used because it will allow stimuli to be easily perceptible and less likely to shift as opposed to other body locations during physically demanding tasks (Merlo et al., 2006). Previous research findings have proven the feasibility of an eight-tactor belt display (Cholewiak, Brill, and Schwab, 2004). Each of the eight tactors was positioned at 45° intervals in the adjustable belt. The tactors could be activated individually, sequentially, or in groups to provide a specific sensation or create unique patterns of vibration. The tactor control unit was capable of receiving wired or wireless signals and converts them into recognizable patterns of vibration. The system, which provides the capability to vary signal frequency, gain, and duration, was powered by a 9.6-V nickel-metal hydride (Ni-MH) battery.

Figure 1. Tactile communications system.

4.2.2 Tactile Patterns

Four tactile patterns were provided via a tactile belt during this experiment. These patterns were developed based on the work of Jones et al. (2006) in which similar tactile patterns were used in a 4 × 4 back display. In figure 2, for each pattern, the numbers indicate the sequence in which tactors vibrated for each tactile command. The duration of each individual tactor vibrations was 500 ms, with a frequency of 250 Hz. Individual tactor vibrations were organized into patterns (figure 2). Within each pattern, individual tactor vibrations were presented in groups of four, with each group containing varying intensity and inter-stimulus intervals (figure 3). The intensity of each pattern was presented at either an EAI gain setting of 2 (12.0 dB) or 4 (23.5 dB), and the inter-stimulus interval of each pattern was either 500 or 0 ms. Therefore, tactile patterns with an inter-stimulus interval of 500 ms had a total duration of 3.5 s, and tactile patterns with an inter-stimulus interval of 0 ms had a total duration of 2.0 s (figure 3). The gain settings refer to the mean ratio of tactor output to the voltage input. The two intensity levels and the two inter-stimulus interval levels were combined to form the four urgency combinations, as shown in table 1.

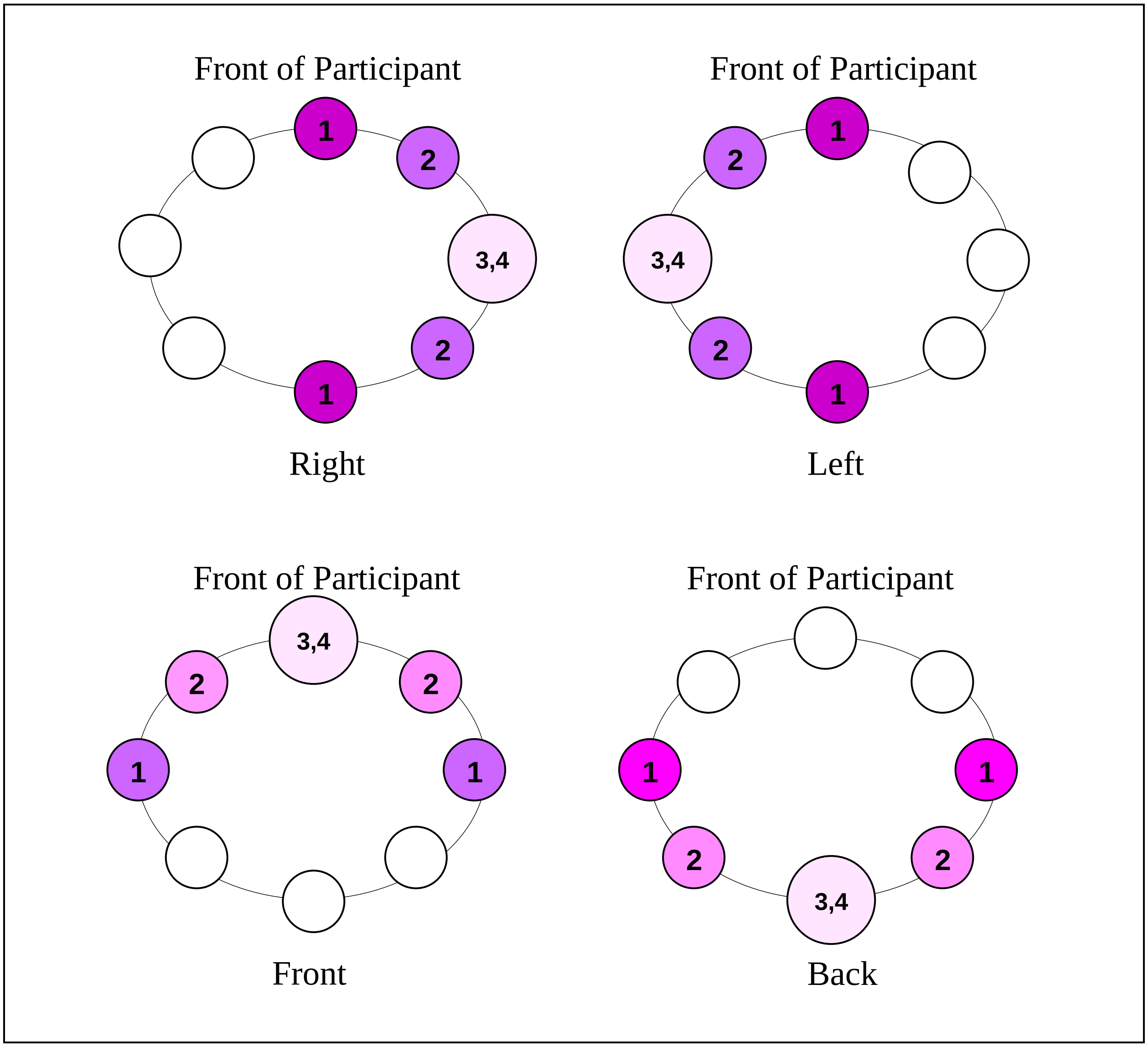

Figure 2. Tactile patterns.

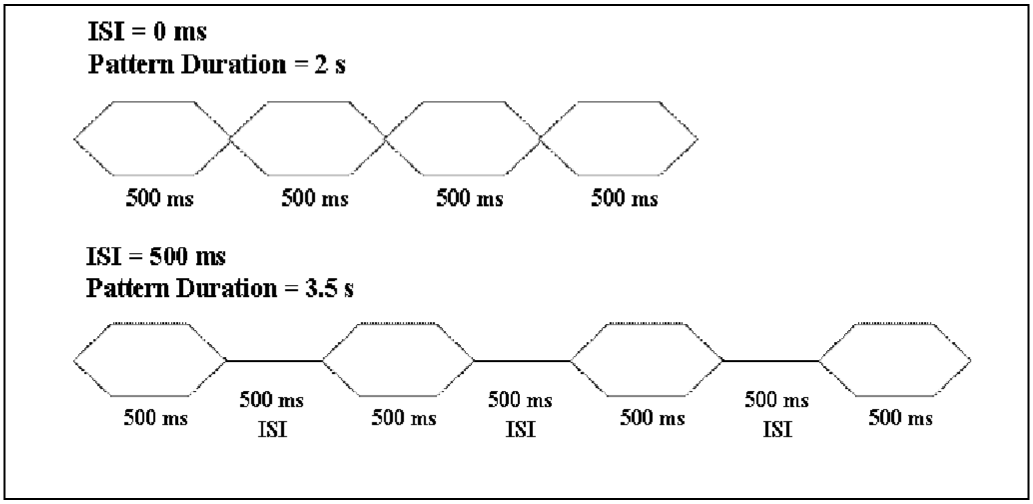

Figure 3. Inter-stimulus interval (ISI) and pattern durations.

Table 1. Urgency combinations.

Inter-Stimulus Interval (ms)	Intensity (dB)
0	12.0
0	23.5
500	12.0
500	23.5

4.2.3 Soldier Equipment

The Soldiers completed this investigation while wearing a basic fighting load as detailed in table 2. They carried a training device simulating the M4 carbine as they maneuvered through the Individual Movement Technique Course described in section 4.2.4.

Table 2. Basic fighting load.

Item Description	Weight (lb)
Underclothing and socks	0.48
Army combat uniform	3.00
Belt with buckle	0.63
Boots	4.10
Army combat helmet (ACH)	3.25
Interceptor body armor (IBA) outer tactical vest (OTV) with front and rear small arms protective insert (SAPI) plates	17.5
1-quart canteen with water and cover, (2 each)	5.00
Inert hand grenades (2 each)	2.00
Individual first aid kit	0.17
M4 rifle	6.65
Ammunition pouches (2 each)	0.46
Elbow and knee pads (2 of each)	2.00

4.2.4 Individual Movement Technique (IMT) Course

The woodland IMT course at Ft. Benning, GA, provides an environment for assessing IMT performance that enables control, standardization, and repeatability (figure 4). It consists of 16 individual obstacles and has two identical lanes. The course design requires Soldiers to use urban and non-urban tactical maneuvers.

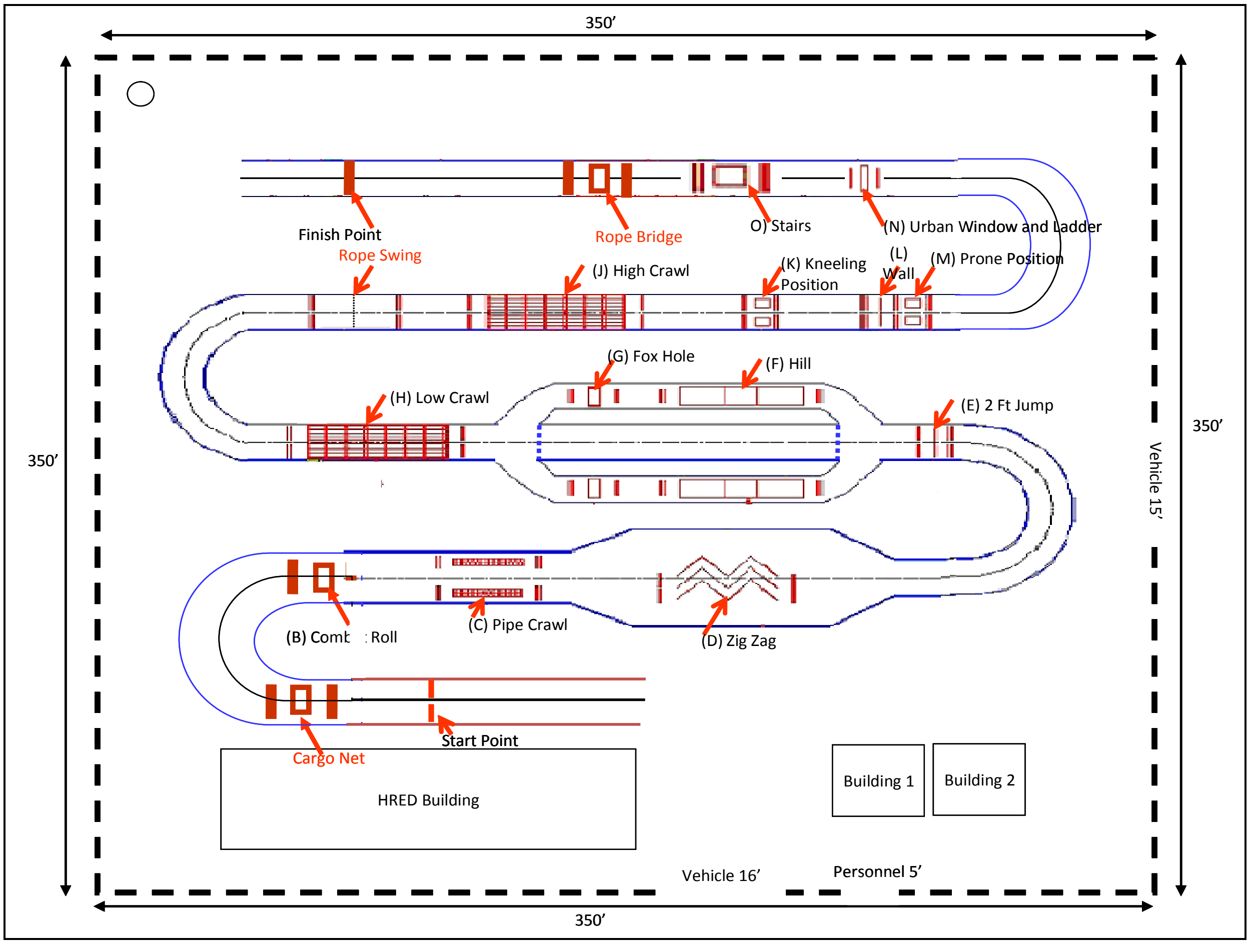

Figure 4. IMT course.

Participants were asked to simply walk around unused obstacles. A description of each obstacle used in this investigation is listed below:

- *Start*. The start point is clearly marked with a white line that spans the width of both lanes on the course. The course requires the Soldier to begin in the upright standing position with the weapon held at the ready. On the command "Go" from the data collector, the trial begins and the Soldier moves ~30 m to the combat roll.

- *Combat Roll*. Each lane of the combat roll station is about 6 m long and 1 m wide. The Soldier assumes the prone position immediately after entering the station. The Soldier then executes a full combat roll to the left or right, pushes off the ground using the butt stock of the weapon, and moves to the next obstacle.

- *Pipe Crawl*. The pipe is 6 m long by 1 m in diameter and made of corrugated steel. It has a ridged surface. However, due to interference with tactile system communications, the Soldiers crawl alongside the pipe.

- *Zigzag*. The zigzag is 1.6 m tall, 14 m in length, and ~1 m in width. It consists of three turns (~90° each) within the lane. The framework is constructed of wood with mesh wire installed between the two lanes and on the outside framework of each lane.

- *2-ft Wall Kneeling Firing Position*. Upon arrival at this station, the Soldier assumes a kneeling supported firing position.

- *Low Crawl*. The low crawl is 13 m long and 3 m wide with an overhead cover of mesh wire ~0.6 m off the ground.

- *Second Bend*. The Soldier walks from the Low Crawl to the next event.

- *High Crawl*. Each lane of the high crawl is 13 m long and 3 m wide with an overhead cover of mesh wire ~1 m off the ground. The Soldier moves as quickly as possible, using correct high crawl procedures, to negotiate the full length of the obstacle.

- *Kneeling Firing Position*. The kneeling firing position station provides a wooden support 2 m wide, 1 m tall, and 13 cm deep for the Soldier to support the weapon against during target acquisition and engagement. Upon entering the station, the Soldier assumes a kneeling supported firing position.

- *4-ft Wall*. The high wall is made of wood, is 1.4 m tall, 1.8 m wide, and 13 cm deep. The Soldier climbs over the obstacle without causing any personal injury or damaging equipment while maintaining control of the weapon at all times.

- *Prone Supported Firing Position*. The prone firing position station is 2 m long by 1 m wide with sandbags provided to support the weapon. The Soldier enters the station and assumes a prone supported firing position.

- *Urban Wall Window*. The Urban wall replicates several urban obstacles. Upon reaching the wall, the Soldier climbs through the opening that represents a window.

- *Ladder*. The Soldier climbs up one side of the wall and down the other while maintaining control of the weapon.

- *Stairs and Platform*. The Soldier climbs up five wooden stairs, crosses a platform, and then goes down five different steps.

- *End Point*. The Soldier moves ~30 m and completes the IMT course.

4.2.5 Questionnaire

Upon completion of the study, a questionnaire was administered to gather each participant's comments, opinions, and perception of the difficulty to detect and identify tactile patterns at the varying urgency levels (appendix A).

4.3 Experimental Design

A 2 × 2 × 4 within-subjects design was used with three independent variables: inter-stimulus interval, stimulus intensity, and pattern. The independent variables and their associated levels are shown in table 3. Each participant completed one static block and three moving blocks during the study. In the static block, participants received tactile patterns while standing still. In the moving blocks, participants received tactile patterns while negotiating obstacles on the IMT course. Each block consisted of 32 trials or 32 random tactile pattern presentations. The order of presentation of the experimental blocks was counterbalanced.

Table 3. Independent variables and levels.

Variable	Levels
Inter-stimulus interval	0 ms, 500 ms
Intensity	12.0 dB, 23.5 dB
Pattern	right, left, front, back

Four dependent variables were measured: (1) ratings of perceived urgency of patterns, (2) the proportion of patterns detected, (3) the overall proportion of patterns correctly identified, and (4) ratings of difficulty of pattern identification. The proportion of patterns detected measured whether a pattern was perceived, regardless of whether it was identified correctly or not. For the overall proportion of patterns correctly identified, undetected patterns and incorrect identification were counted as errors.

4.4 Training

Each volunteer was briefed on the purpose of the investigation, the procedures to be followed during the study, and any risks involved in their participation. The investigator read the volunteer agreement affidavit aloud to the participant who followed along (appendix B) and addressed any questions the participant might have had regarding the study. If the volunteer agreed to take part in the investigation, the volunteer completed the information on the last page of the affidavit and signed it. A demographic questionnaire was then administered to obtain pertinent information on the volunteer's background (appendix C).

Next, participants were introduced to the specific obstacles that were used during the experiment and an investigator explained the proper technique to negotiate each obstacle on the IMT course. Each participant then donned an undershirt with six belt loops sewn around the torso level to

ensure that the tactile belt remained in place for the duration of the experiment. An experimenter then placed the tactile belt on the participant using all the belt loops, and the tactile control box was placed in the right pocket of the participant's trousers (figure 5). They were then trained on the tactile patterns. For the tactile pattern training, participants were given a paper copy of the tactile patterns and received a brief explanation of each pattern. Participants were then provided each pattern several times to allow them to become familiar with how each tactile pattern felt. Next, the tactile patterns were provided in a random order, and the participant was asked to verbalize which pattern they received. The participants were not trained on the varying intensity and inter-stimulus interval levels. The investigator informed participants if they made any identification errors. Once participants became 100% accurate in identifying tactile patterns, the testing began.

Figure 5. Participant donning tactile system.

4.5 Testing

During the experiment, each participant completed one static block and three moving blocks. The static block was completed first, and then the three moving blocks were completed. Participants received 32 patterns during each block. During each block, the participants verbally identified tactile patterns and indicated their perceived urgency level under various levels of stimulus intensity (12.0 and 23.5 dB) and inter-stimulus interval (0 and 500 ms). Ratings were based on a scale of 1 to 10, with 10 indicating extremely high urgency. Responses were recorded by the investigator. A typical response would be "Right – 7." A 30-min break was given after each moving block of the data collection. Upon completion of the experiments, participants completed a questionnaire about their experience of the tactile patterns and their urgency levels. This questionnaire allowed participants to rate how well they were able to detect and identify tactile patterns. Total time to complete the experiment was ~3 h.

5. Results

Separate analyses of variance (ANOVA) were conducted on the ratings of perceived urgency, percentage of patterns detected, and percentage of patterns correctly identified; Statistical significance was concluded when $p < 0.05$. Significant effects were examined post hoc with the least significance difference (LSD) test. Means and standard error of the means are presented in figures 6–13. Descriptive statistics (means and standard error of the means) are presented in appendix D.

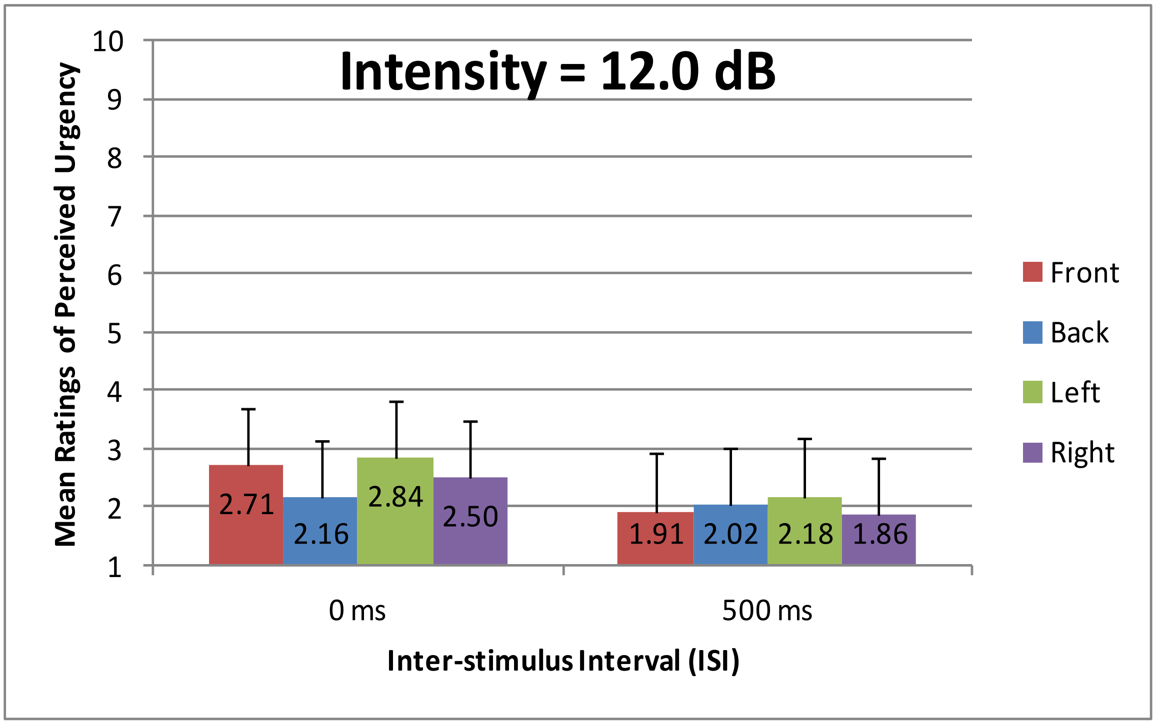

Figure 6. Inter-stimulus interval × intensity × pattern interaction (static trials) at 12.0 dB intensity.

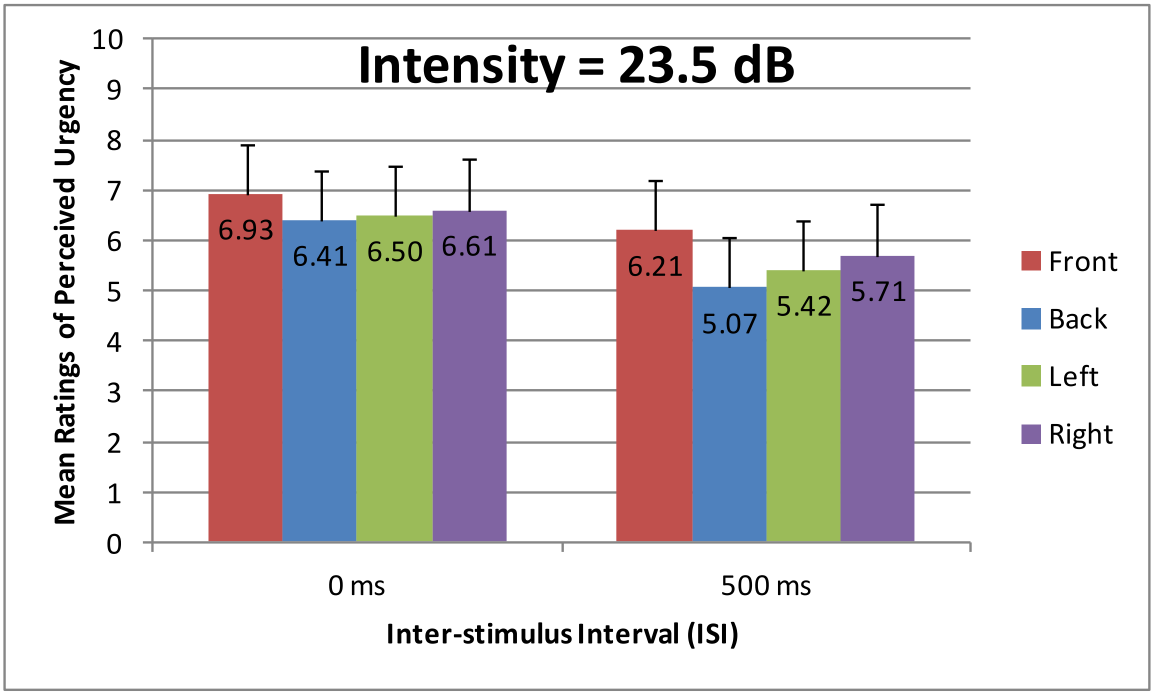

Figure 7. Inter-stimulus interval × intensity × pattern interaction (static trials) at 23.5 dB intensity.

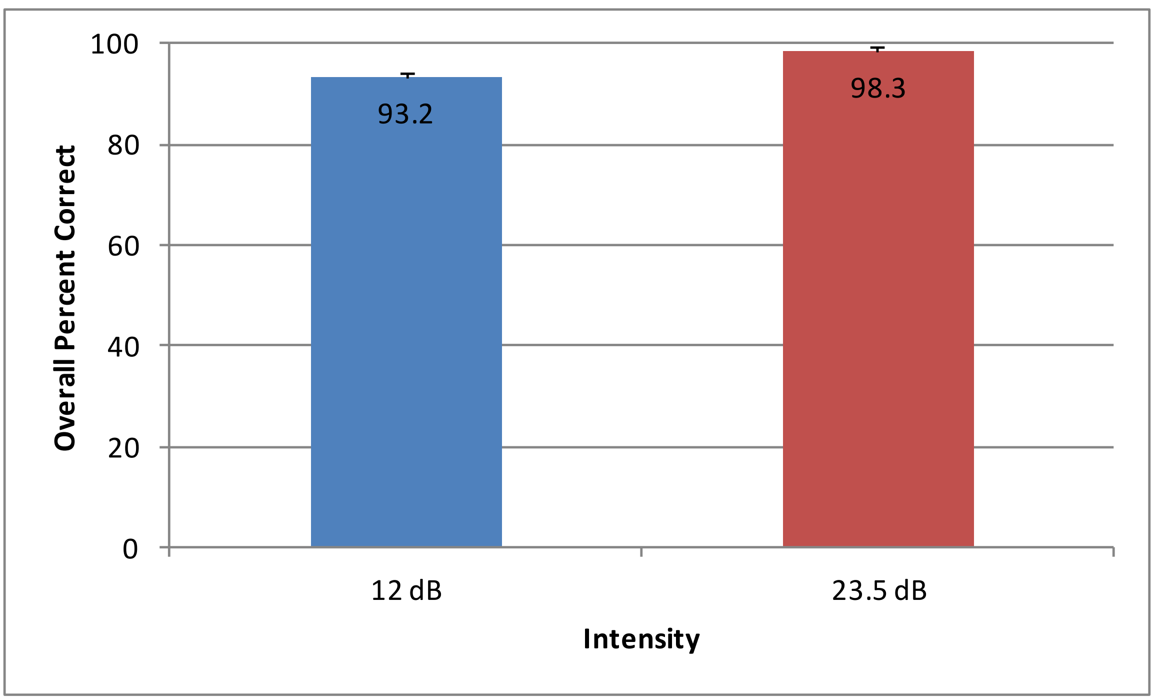

Figure 8. Main effects of intensity (overall percent correct).

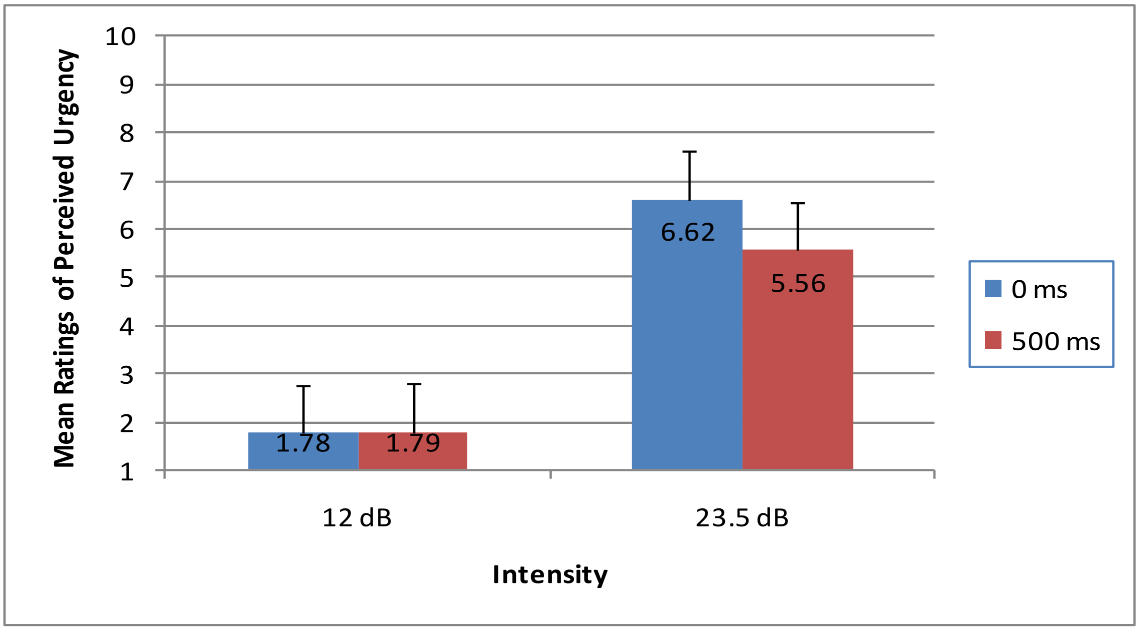

Figure 9. Inter-stimulus interval × intensity interaction (mean ratings of perceived urgency).

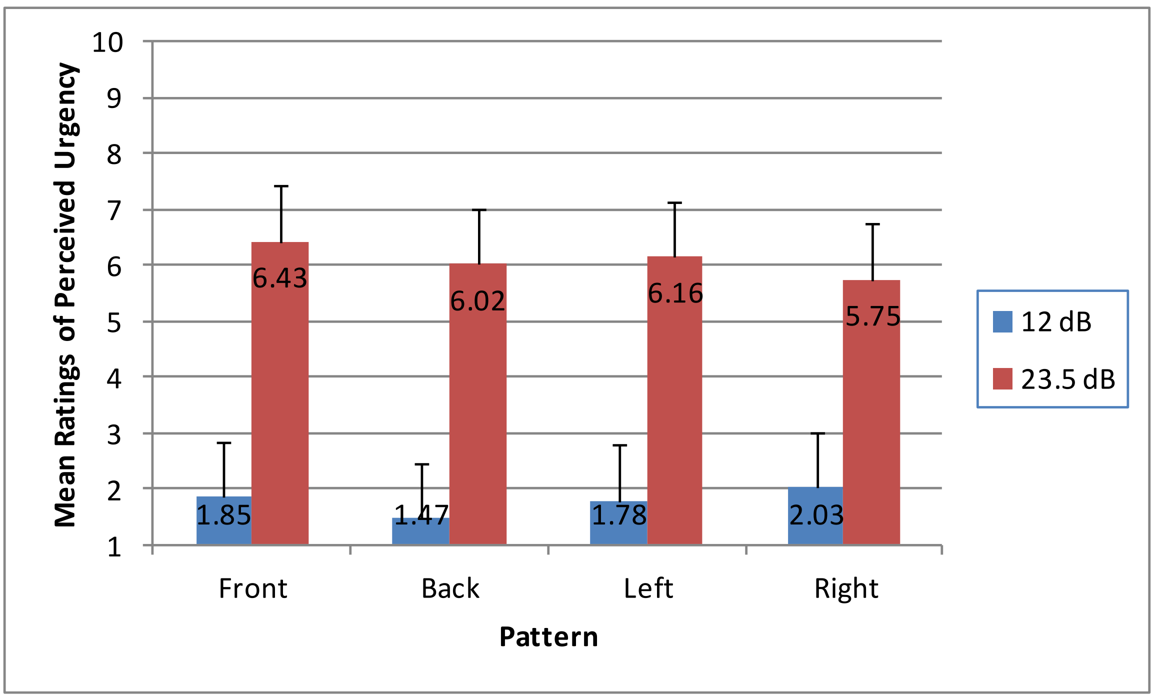

Figure 10. Intensity × pattern interaction (mean ratings of perceived urgency).

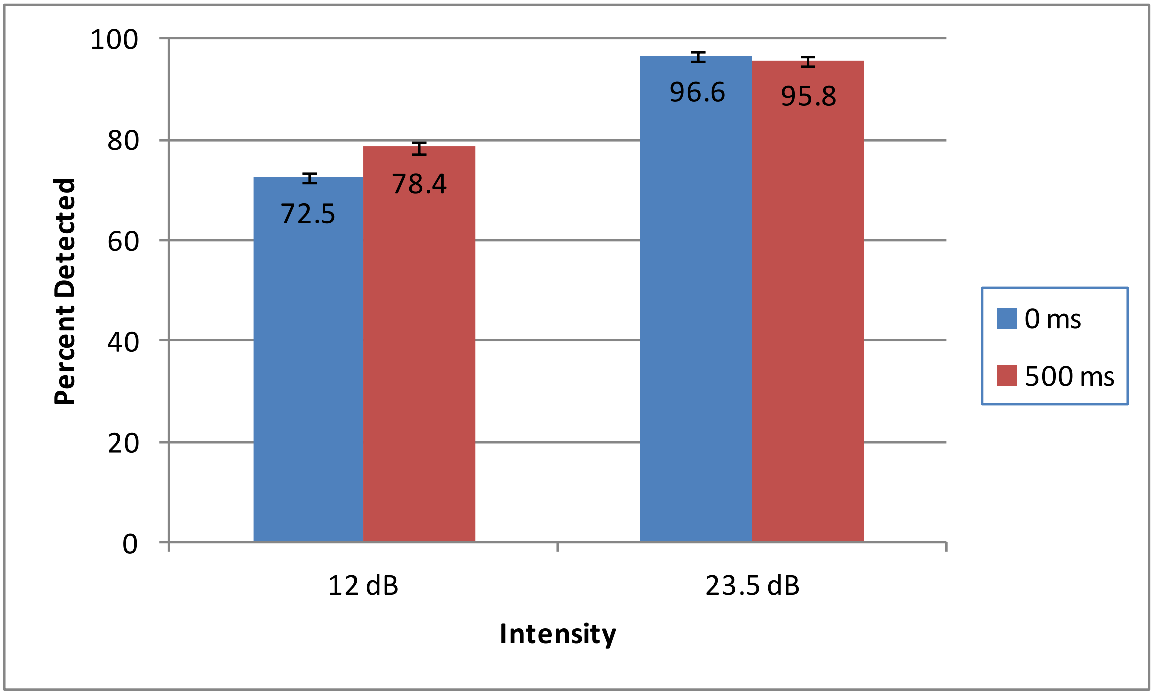

Figure 11. Inter-stimulus interval × intensity interaction (percent detected).

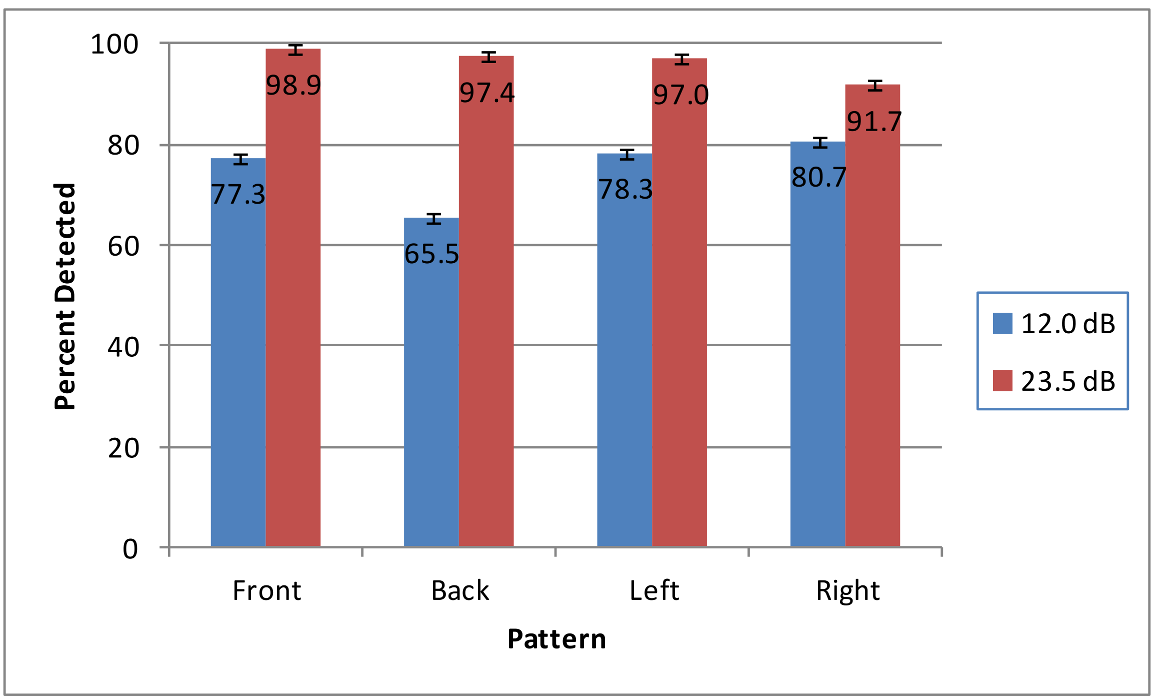

Figure 12. Intensity × pattern interaction (percent detected).

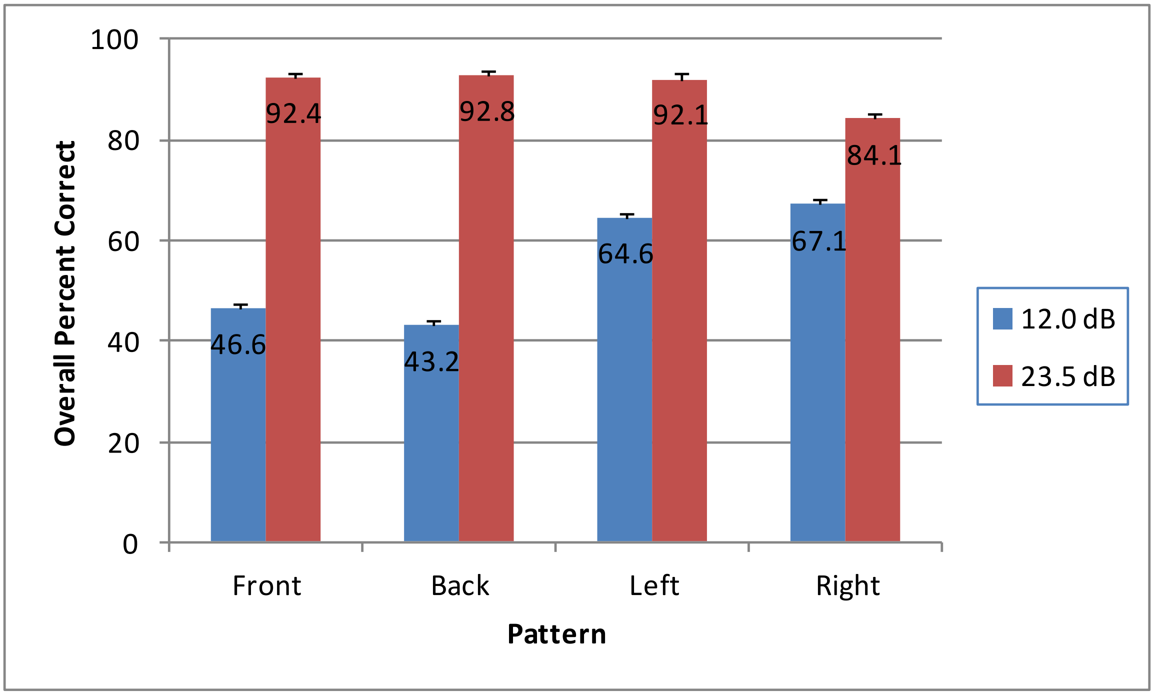

Figure 13. Intensity × pattern interaction (overall percent correct).

5.1 Static Trials

5.1.1 Perceived Urgency

The analysis of the ratings of perceived urgency revealed an Inter-Stimulus interval × intensity × pattern interaction, $F(3, 63) = 3.481$, $p = 0.021$, *partial* $Eta^2 = 0.142$, with main effects of inter-stimulus interval, $F(1, 21) = 12.116$, $p = 0.002$, *partial* $Eta^2 = 0.366$, intensity, $F(1,21) = 157.477$, $p < 0.001$, *partial* $Eta^2 = 0.882$, and pattern, $F(3, 63) = 4{,}815$, $p = 0.004$, *partial* $Eta^2 = 0.187$. No other main effects or interactions were found.

The inter-stimulus interval × intensity × pattern interaction is shown in figures 6 and 7. Post-hoc analyses revealed that all patterns presented at 23.5 dB intensity were rated as significantly more urgent than those presented at the 12.0 dB intensity for both the 0 ms ISI and 500 ms ISI.

When considering the 12.0 dB intensity level, no significant differences in perceived urgency ratings were found for patterns presented at the 0 ms ISI or the 500 ms ISI level; however when comparing across ISI levels, the Front pattern showed differences in ratings of perceived urgency, with the 0 ms ISI pattern rated as significantly higher than the 500 ISI pattern.

At the 23.5 dB intensity level, no significant differences in perceived urgency ratings were found for patterns presented at the 0 ms ISI level. At the 500 ms ISI level, participants rated the front pattern as more urgent than the back and left patterns. When comparing the ratings of perceived urgency across the ISI levels, the back, left, and right patterns presented at 0 ms ISI were rated as more urgent than those patterns were presented at 500 ms ISI. No other significant effects were

found. From these data, it appears that the main effects of inter-stimulus interval, intensity, and pattern are explained by the inter-stimulus interval × intensity × pattern interaction (figures 6 and 7).

5.1.2 Percent Detected

Participants were able to detect 100% of the tactile patterns during the static trials.

5.1.3 Overall Percent Correct

The analysis of the percentage of correctly identified patterns revealed a main effect of intensity, $F(1,21) = 4.738$, $p = 0.041$, *partial* $Eta^2 = 0.184$. Identification rates were significantly higher when patterns were presented at the 23.5 dB intensity than at the 12.0 dB intensity. The main effects are shown in figure 8. No other main effects or interactions were found.

5.2 Moving Trials

5.2.1 Perceived Urgency

The analysis of the ratings of perceived urgency revealed an inter-stimulus interval × intensity interaction, $F(1, 21) = 20.99$, $p < 0.001$, *partial* $Eta^2 = 0.500$, and an intensity × pattern interaction, $F(3, 63) = 8.438$, $p < 0.001$, *partial* $Eta^2 = 0.287$, with main effects of inter-stimulus interval, $F(1, 21) = 9.513$, $p = 0.006$, *partial* $Eta^2 = 0.312$, intensity, $F(1, 21) = 191.498$, $p < 0.001$, *partial* $\mathrm{Eta}^2 = 0.901$, and pattern, $F(3, 63) = 5.373$, $p = 0.002$, *partial* $Eta^2 = 0.204$. No other main effects or interactions were found.

The inter-stimulus interval × intensity interaction is shown in figure 9. Post hoc analyses revealed that the mean ratings of perceived urgency were affected differently by signal intensity and inter-stimulus interval. Specifically, at the 12.0 dB signal intensity, mean ratings of perceived urgency were consistent across the two levels of ISI. However, at the 23.5 dB intensity, signals with an ISI of 0 ms were rated as significantly more urgent than 500 ms ISI signals. Additionally, participants rated the more intense 23.5 dB signals at both the 0 and 500 ms ISI as more urgent than the 12.0 dB signals at the 0 and 500 ms ISI. No other significant differences were found.

The intensity × pattern interaction is shown in figure 10. Post-hoc analyses revealed that the 23.5 dB intensity level was rated as significantly more urgent than the 12.0 dB intensity level across all four tactile patterns. At 23.5 dB, the “front” pattern was rated as significantly more urgent than the “back” and “right” patterns but not the left pattern. Ratings of perceived urgency for the “left” and “back” patterns presented at the 23.5 dB intensity were significantly higher than the “right” pattern presented at the 23.5 dB intensity. At the 12.0 dB signal intensity, there were no significant differences between the “front,” “right’” and “left” patterns. However the “front” and “right” patterns presented at the 12.0 dB intensity were significantly more urgent than the “back” pattern presented at 12.0 dB. No other significant effects were found.

5.2.2 Percent Detected

The analysis of the percentage of detected patterns revealed an inter-stimulus interval × intensity interaction, $F(1, 21) = 7.854$, $p = 0.011$, *partial* $Eta^2 = 0.272$, and an intensity × pattern interaction, $F(3, 63) = 9.190$, $p < 0.001$, *partial* $Eta^2 = 0.304$, with main effects of inter-stimulus interval, $F(1, 21) = 5.210$, $p = 0.033$, *partial* $Eta^2 = 0.199$, intensity, $F(1, 21) = 53.203$, $p < 0.001$, *partial* $Eta^2 = 0.717$, and pattern, $F(3, 63) = 5.165$, $p = 0.003$, *partial* $Eta^2 = 0.197$. No other main effects or interactions were found.

The inter-stimulus interval × intensity interaction is shown in figure 11. Post-hoc analysis revealed that detection rates were consistent across the two levels of ISI at the 23.5 dB intensity level. However, at the lower intensity 12.0 dB signal, detection rates were significantly higher for 500 ms ISI than 0 ms ISI. When comparing across intensity levels, detection rates at 23.5 dB at both ISI levels were significantly better than the 12.0 dB intensity at the 0 and 500 ms ISI levels. No other significant differences were found.

The intensity × pattern interaction is shown in figure 12. Post hoc analysis revealed that detection rates for all patterns presented at the 23.5 dB intensity were significantly higher than all patterns presented at the 12.0 dB intensity level. Detection rates were the lowest for the “back” pattern provided at the 12.0 dB intensity. At the 23.5 dB intensity, detection rates for the “front” pattern were significantly higher than for the “right” pattern. The “back” pattern was also significantly higher than the “right” pattern ($p = 0.039$); however, the difference in mean detection rates between the “left” and “right” patterns only approached significance ($p = 0.054$). From these data, it appears that the main effects of inter-stimulus interval, intensity, and pattern are explained by the inter-stimulus interval × intensity interaction (figure 11) and the Intensity × pattern interaction (figure 12).

5.2.3 Overall Percent Correct

The analysis of the percentage of correctly identified patterns revealed an intensity × pattern interaction, $F(3, 63) = 28.470$, $p < 0.001$, *partial* $Eta^2 = 0.575$, with main effects of intensity, $F(1, 21) = 76.315$, $p < 0.001$, *partial* $Eta^2 = 0.784$, and pattern, $F(3, 63) = 6.147$, $p = 0.001$, *partial* $Eta^2 = 0.226$. No other interactions or main effects were found.

The intensity × pattern interaction is shown in figure 13. Post hoc analysis revealed that participants were able to correctly identify a significantly higher percentage of patterns at the higher 23.5 dB intensity level than at the lower 12.0 dB intensity level. For the patterns presented at the 12.0 dB intensity level, identification rates were significantly lower for the “back” and “front” patterns than for the left and right patterns. The “front,” “back,” and “left” patterns presented at the 23.5 dB intensity yielded significantly higher detection rates than the “right” pattern presented at the 23.5 dB intensity. From these data and closer examination of figure 13, we can assume that the intensity and pattern main effects can be attributed to the interaction effects of intensity and pattern.

5.3 Subjective Ratings of Difficulty

The questionnaire responses were coded to a scale of 1 to 7, with 1 representing "Extremely Easy" and 7 representing "Extremely Difficult." The means and SD were computed for the three difficulty ratings. The mean rating of difficulty in detecting patterns was 3.23 (SD = 1.15). The mean rating of difficulty in identifying patterns was 3.09 (SD = 1.48). The mean rating of difficulty in distinguishing urgency levels was 2.45 (SD = 1.41).

6. Discussion

The objective of this investigation was to examine the effects of inter-stimulus interval and stimulus intensity on perceived urgency and the detection and identification of tactile patterns for Soldiers performing dismounted maneuvers. Findings of this study are discussed in light of the dependent variables and hypotheses.

It was hypothesized that tactile patterns would be perceived as more urgent when they were presented at the stronger 23.5 dB intensity with no ISI, and tactile patterns would be perceived as less urgent when they were presented at the 12.0 dB intensity with the slower 500 ms ISI. In the static conditions, ratings of perceived urgency were the highest for those patterns presented at the 23.5 dB intensity with a 0 ms ISI. The ratings of perceived urgency were the lowest for the patterns presented at the 12.0 dB intensity with the 500 ms ISI. In regard to detection, all tactile patterns were detected in the static condition, and tactile patterns were correctly identified with 96% accuracy. However, the percentage of correctly identified patterns presented at the weaker 12.0 dB intensity was 93%, while the percentage of correctly identified patterns presented at the stronger 23.5 dB intensity was 98%. These findings are consistent with the findings of a previous laboratory study in which participants perceived tactile patterns as more urgent when they were presented at the stronger 23.5 dB intensity with no ISI and tactile patterns as less urgent when they were presented at the 12.0 dB intensity with the slower 500 ms ISI (White, 2011). Similarly, in the White (2011) study, detection rates were approximately 99% and identification rates were ~97%.

In order to determine the feasibility of adding urgency to tactile patterns in dismounted-relevant environments, it is imperative to examine detection, identification, and the perception of tactile patterns at the varying intensity and ISI levels in those environments. Therefore, in this investigation, participants received tactile patterns at the four urgency combinations while negotiating walking, kneeling, crawling, and climbing obstacles. In the moving conditions, patterns were rated most urgent when they were provided at the stronger 23.5 dB intensity with no ISI. ISI had no effect on the ratings of perceived urgency of patterns presented at the weaker 12.0 dB intensity. Findings also revealed that the "front" pattern provided at the 23.5 dB intensity was rated as more urgent than all other patterns. Although it seems logical for ratings

of perceived urgency for the “left” and “right” patterns to be comparable, at the 23.5 dB intensity, it is not known why the “left” pattern was rated as more urgent than the “right” patterns. The investigators retested the tactile systems to ensure that this finding was not due to an error in the programming of the tactile systems. The “back” pattern was also rated as more urgent than the “right” patterns. Despite these findings, in genera1, patterns presented at the stronger 23.5 dB intensity were all rated as more urgent than the pattern presented at the weaker 12.0 dB intensity.

Findings of this investigation indicate that intensity, ISI, and pattern had a significant effect on detection. During the moving trials 86% of tactile patterns were detected. More patterns presented at the stronger 23.5 dB intensity were detected than those at the weaker 12.0 dB. At the 12.0 dB intensity, the more distinct patterns presented with the 500 ms ISI were detected than those presented with no ISI. The patterns presented at the weaker 12.0 dB intensity with no ISI were more easily missed while negotiating obstacles on the IMT course. The “front” pattern presented at the 23.5 dB intensity was detected more than all other patterns. Although detection rates for the “left” and “back” patterns were marginally higher than the “right” pattern, the detection rates were all above 92%. At the weaker 12.0 dB intensity, the “back” pattern was detected less than all other patterns.

Intensity and pattern had effects on the correct identification of patterns. Patterns presented at the 23.5 dB intensity were correctly identified more often than all patterns presented at the 12.0 dB intensity. Again, the “front,” “back,” and “left” patterns were correctly identified more than the “right” pattern. At the 12.0 dB intensity, the “left” and “right” patterns were correctly identified more than the “front” and “back” patterns. The results regarding the “front” pattern are consistent with the findings of Redden et al. (2006) who found that localization of tactile signals was degraded when the torso is in contact with a surface such as during crawling and climbing obstacles. In regard to the “back” pattern, Krausman and White (2008) found that during bumpy, shifty vehicle movements, localization rates for tactile signals provided to the back were degraded. This may also be true of the bumpy movements of the climbing and crawling obstacles on the IMT course.

Participants rated tactile patterns provided at the stronger 23.5 dB intensity with no ISI the most urgent and the patterns provided at the lower 12.0 dB intensity with the 500 ms least urgent in the static condition. This supports the hypothesis that states that patterns that have a 0 ms inter-stimulus interval and a 23.5 dB intensity would be rated the most urgent and the patterns with a 500 ms inter-stimulus interval and a 12.0 dB intensity would be rated the least urgent. The moving trials partially support this hypothesis in that the patterns presented at the 23.5 dB intensity with no ISI were rated most urgent, but at the 12.0 dB intensity, there was no difference in ratings of perceived urgency based on ISI. In regard to the hypothesis that states that tactile patterns presented at the weaker 12.0 dB intensity would be more difficult to detect and identify, the findings of this research reveal that detection and identification rates were all lower at 12.0 dB intensity than at 23.5 dB in the moving trials.

Based on the subjective questionnaires, participants felt that it was relatively easy to detect, identify, and distinguish between urgency levels. The specific comments that were made by Soldiers in the post experiment questionnaire reflect the findings of the objective data reported. In general, participants indicated that it was more difficult to detect and identify patterns at the lower 12.0 dB intensity. They also confirmed that it was more difficult to detect and identify patterns when negotiated the more strenuous obstacles like crawling and climbing. Some participants also felt that patterns presented at the weaker 12.0 dB intensity were more difficult to distinguish. This is reflected objective data for the urgency ratings of the moving trials at the 12.0 dB intensity. The objective and subjective findings of this investigation indicate the feasibility of adding urgency to tactile patterns.

7. General Discussion

This investigation was conducted as part of a three-year Technology Program Agreement (TPA) to investigate how the tactile modality can be used as a communication medium in military environments. This effort specifically examined the type of information that can be relayed to the Soldier using the tactile modality. In year one, the TPA began with a thorough literature review of tactile research to determine what has been done in the area of tactile displays. Also, in addition to the literature review, a tactile workshop that featured tactile researchers from academia and the military was conducted. These researchers shared their past research experiences and also provided input on the direction of future research. In the second year, a laboratory study to examine the effects of ISI and intensity on the perceived urgency and the detection and identification of tactile patterns. During the third year, this field investigation was conducted to examine the effects of ISI and intensity on the perceived urgency and the detection and identification of tactile patterns while performing dismounted maneuvers.

The literature review that was conducted during the first year of the TPA specifically looked at the types of information that can be presented using tactile displays and the identification of body areas that are best suited for receipt of that information. Based on the findings of the literature review, although most Army-relevant tactile research employs the upper limbs and the torso, the torso is the most feasible body location to provide dismounted Soldiers with vibrotactile stimulation (White, 2010). The torso is a stable, body-centered, and three-dimensional (3-D) (Gilson, Redden, and Elliott, 2007; Van Erp, 2007). The literature review indicates that the torso has been successfully used to provide tactile signals as well as tactile patterns to dismounted Soldiers.

In an effort to explore the feasibility of providing more complex tactile patterns to Soldiers, in the second year of the TPA, a laboratory study was conducted to determine the feasibility of providing a sense of urgency to tactile patterns. The effects of ISI and intensity on the perceived

urgency and the detection and identification of tactile patterns were examined. The findings of this research revealed that participants were able to detect and identify tactile patterns and their urgency levels with nearly 100% accuracy. Tactile patterns provided with no ISI at the 23.5 dB intensity were rated the most urgent, and patterns with the 500 ms ISI at the 12.0 dB intensity were rated the least urgent. The findings of this investigation led to the current research effort, which examined the effects of ISI and intensity on the perceived urgency and the detection and identification of tactile patterns while performing dismounted maneuvers.

The findings of the research conducted under this TPA reveal the feasibility of adding urgency to tactile patterns in dismounted environments. Based on the percentage of patterns detected and the percentage of patterns correctly identified, for dismounted applications, it may be best to provide all patterns at the stronger 23.5 dB intensity and vary urgency using different levels of ISI. Future research should look at the number of ISI levels that can be perceived by Soldiers while performing dismounted maneuvers. Using intensity to provide urgency may be best suited for mounted applications. If intensity is to be used to provide urgency during dismounted maneuvers, stronger levels of intensity should be explored. However, as stronger intensity levels are examined, the intensity levels should be examined to ensure that they are not unpleasant to Soldiers. A closer look should be taken at how different obstacle types affect the detection and identification of tactile patterns at their varying urgency levels. Because it is not known how many tactile patterns Soldiers can learn, an examination of the number of tactile patterns with their varying urgency levels that may be feasible for Soldiers in dismounted environments should be investigated. If the limit of the number tactile patterns that a Soldier can learn is reached, this can cause confusion and result in reduced mission performance. Increasing the intensity of tactors can create audible noise. Future investigations should look at minimizing that noise or employing quieter tactors. The findings of this research may also be useful in exploring the use of urgency in mounted environments as well.

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Appendix A. Post-Experiment Questionnaire

This appendix is in its original form, without editorial change.

Post-Experiment Questionnaire

Participant #: ___ Trial ___

Answer each question below by placing an "X" in the bracket that best describes your experience in the experimental trial you *just* completed.

Please answer the following question.

1. How easy or difficult was it to DETECT the tactile patterns?

Extremely Difficult			*Neither Difficult Nor Easy*			*Extremely Easy*
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Comments: ____

____

____

2. How easy or difficult was it to IDENTIFY the tactile patterns?

Extremely Difficult			*Neither Difficult Nor Easy*			*Extremely Easy*
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Comments: ____

____

____

3. How difficult or easy was it to identify the URGENCY levels?

Extremely Difficult			*Neither Difficult Nor Easy*			*Extremely Easy*
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Comments: ____

____

____

Appendix B. Volunteer Agreement Affidavit

This appendix is in its original form, without editorial change.

Consent Form
Army Research Laboratory, Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005

Title of Project**:** Detection and Identification of Tactile Pattern Urgency While Performing Dismounted Maneuvers

Project Number: ARL 11-028

Sponsor: Army Research Laboratory

Principal Investigator: Timothy L. White
Army Research Laboratory
Human Research & Engineering Directorate
RDRL-HRS-B, Bldg. 459
Aberdeen Proving Ground, MD 21009
(410) 278-5884; timothy.l.white1@us.army.mil

Associate Investigators: Andrea S. Krausman
Army Research Laboratory
Human Research & Engineering Directorate
RDRL-HRS-B, Bldg. 459
Aberdeen Proving Ground, MD 21009
(410) 278-5933; andrea.krausman@us.army.mil

Rodger A. Pettitt
Human Factors Integration Division
Weapons Branch
MCoE Field Element
(706) 545-9142; rodger.pettitt@us.army.mil

You are being asked to join a research study. This consent form explains the research study and your part in it. Please read this form carefully before you decide to take part. You can take as much time as you need. Please ask the research staff any questions at any time about anything you do not understand. You are a volunteer. If you join the study, you can change your mind later. You can decide not to take part now or you can quit at any time later on.

Purpose of the Study

The purpose of this study is to investigate the value of using vibrators to present information to individuals while they run an obstacle course. You are being invited to participate because you are in good health and are not taking medications for any health reasons.

Procedures to be Followed

Prior to beginning the study, you will fill out a demographics questionnaire. Then, you will be asked to don a t-shirt that you will wear for the duration of the experiment. You will notice that the t-shirt has several belt loops arranged around your torso. You will also be asked to don a belt containing 8 vibrators that when activated will feel like someone is rapidly tapping your skin. An experimenter of the same sex will place the belt through the t-shirt loops to hold the belt secure around your waist.

During the study you will walk through the IMT course and maneuver through each of the obstacles. At certain times you will feel a vibratory pattern being presented to the belt around your waist. Your role is to verbally indicate what pattern you felt and also how urgent the pattern felt. Before the testing period, you will be trained on the vibratory patterns, the urgency levels, and familiarized with the obstacle course.

There will be a total of four trials in this experiment. One trial will be stationary and the remaining three will be moving through the IMT course. In the stationary trial, you will identify vibratory patterns and provide an urgency rating while standing still. In the other three trials, you will maneuver through the obstacle course at a brisk walking pace while performing the pattern identification and urgency rating task. You will rate the urgency of the vibratory patterns you receive on a scale of 1 to 10, with 1 indicating an extremely non-urgent pattern, and 10 indicating an extremely urgent pattern. Urgency ratings that are twice as high as others will signify levels of urgency twice as high – for example, an urgency level of 8 is twice as urgent as an urgency level of 4. Vibratory patterns will be presented in random order with varying intensity and inter-stimulus intervals during each block. When vibratory patterns are received, you will be asked to verbalize the vibratory pattern received and rate its urgency (for example: "Turn Right – 7").

After the experiment, you will be asked to complete a questionnaire to rate how well you were able to identify vibratory patterns while maneuvering through the obstacle course. You will be given the opportunity to rest for at least 30 minutes after each trial. The investigator will record any comments that you may have during this investigation.

Discomforts and Risks

The risks associated with this experiment are considered minimal. The risks that will be encountered during this investigation are typical of the risks encountered when training and performing duties pertaining to your military occupational specialty. The risks include physical

exhaustion, muscle strains, cuts, and abrasions. Please inform investigators if you experience any discomfort or problems during the investigation.

Outdoor activities will be suspended during any weather conditions that are inherently dangerous or will cause the investigation trials to be dangerous. To combat the possibility of dehydration or heat related injuries, you are encouraged to take water breaks at least every 30 minutes. Drinking water will be provided.

All other risks anticipated in this evaluation are typical of the everyday risks encountered while working out of doors. There is a risk of tick bites and the potential for Lyme disease. You will be asked to inspect yourself frequently for ticks. Flying insects at the site are also a concern. You are encouraged to use insect repellent, which will be available on site. If you are bitten please notify the principal investigator so that closer visual monitoring of that participant will occur. There are also wild animals in the surrounding area.

Benefits

There are no personal benefits for you for taking part in this study. However, your participation will provide valuable information about Soldier performance that will assist in the design of future Army systems.

Duration

It will take approximately 3.5 hours for you to take part in this study.

Confidentiality

Your participation in this research is confidential. The data will be stored and secured at Aberdeen Proving Ground, in a locked file cabinet. The data, without any identifying information, will be transferred to a password-protected computer for data analysis. After the data is put in the computer file, the paper copies of the data will be shredded. This consent form will be sent to Army Research Laboratory's Institution Review Board, where it will be retained for a minimum of three years.

If the results of the experiment are published or presented to anyone, no personally identifiable information will be shared. Publication of the results of this study in a journal or technical report, or presentation at a meeting, will not reveal personally identifiable information. The research staff will protect you data from disclosure to people not connected with the study. However, complete confidentiality cannot be guaranteed because officials of the U. S. Army Human Research Protections Office and the Army Research Laboratory's Institutional Review Board are permitted by law to inspect the records obtained in this study to insure compliance with laws and regulations covering experiments using human subjects.

We would like your permission to take pictures during the experimental session. The pictures will be printed in technical reports and shown during presentations when we describe the results of the study. To protect your identity, we will pixelate the image to obscure your face. You can still be in the study if you prefer not to be photographed. Please indicate below if you will agree to allow us to take pictures of you.

I give consent to be photographed during this study: ____Yes ____No
please initial:____

Contact Information for Additional Questions

You have the right to obtain answers to any questions you might have about this research both while you take part in the study and after you leave the research site. Please contact anyone listed at the top of the first page of this consent form for more information about this study. You may also contact the Chairperson of the Human Research & Engineering Directorate, Institution Review Board, at (410) 278-5992 with questions, complaints, or concerns about this research, or if you feel this study has harmed you. The chairperson can also answer questions about your rights as a research participant. You may also call the chairperson's number if you cannot reach the research team or wish to talk to someone else.

Voluntary Participation

Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive by staying in it.

Military personnel cannot be punished under the Uniform Code of Military Justice for choosing not to take part in or withdrawing from this study, and cannot receive administrative sanctions for choosing not to participate.

Civilian employees or contractors cannot receive administrative sanctions for choosing not to participate in or withdrawing from this study.

You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study based on the information outlined above, please sign your name and the date below.

You will be given a copy of this consent form for your records.

This consent form is approved from 9 May 2011 to 8 May 2012.

Do not sign after the expiration date of 8 May 2012

____________________________________ ___________________

Participant Signature Date

____ ___________________

Person Obtaining Consent Date

Appendix C. Demographics Questionnaire

This appendix is in its original form, without editorial change.

Demographics Form

1. Participant #: _____ **2. Date: ________________**

3. Age: ______ **4. Gender: M F** **5.Contacts/Glasses: Y N**

6. Do you have any physical injury at the present time that would prevent you from maneuvering through the obstacle course, wearing the tactile belt, or feeling the tactile vibrations?

Y N

If yes, please describe:

____

7. Have you had any surgery in the last two months that would prevent you from maneuvering through the obstacle course, wearing the tactile belt, or feeling the tactile vibrations?

Y N

If yes, please describe:

____

8. Are you presently on a profile of any type?

Y N

If yes, please describe your current limitations:

____

10. Military Data
a. Grade:_________
b. Primary MOS/AFSC: _________ c. Time in MOS/AFSC Years_______ Months______
c. Duty Position/Title: ____
d. Time in present duty position: Years: ______ Months: ______
e. Length of service? Years: ______ Months: ______
d. Do you have combat experience? Y N
If yes, identify location, time frame and your duty position:

____

____

Appendix D. Descriptive Statistics [Means and Standard Error of the Means (SEM)]

This appendix is in its original form, without editorial change.

1. Static Trials

A. Ratings of Perceived Urgency

Inter-stimulus Interval (ISI)

ISI	Mean	SEM
0 ms	4.58	0.14
500 ms	3.80	0.14

Intensity

Intensity	Mean	SEM
12.0 dB	2.27	0.09
23.5 dB	6.11	0.10

Pattern

Intensity	Mean	SEM
Back	3.92	0.20
Front	4.44	0.21
Left	4.24	0.20
Right	4.17	0.19

ISI x Intensity x Pattern

ISI	Intensity	Pattern	Mean	SEM
0	12.0	Back	2.16	0.25
		Front	2.71	0.28
		Left	2.84	0.34
		Right	2.50	0.26
0	23.5	Back	6.41	0.27
		Front	6.93	0.27
		Left	6.50	0.25
		Right	6.61	0.23
500	12.0	Back	2.02	0.28
		Front	1.91	0.18
		Left	2.18	0.27
		Right	1.86	0.17
500	23.5	Back	5.07	0.30
		Front	6.21	0.34
		Left	5.42	0.30
		Right	5.71	0.27

B. Percent Detected (Participants detected 100% of patterns during the static trials)

C. Overall Percent Correct

Intensity

Intensity	Mean	SEM
12.0 dB	93.2	1.34
23.5 dB	98.3	0.69

2. **Moving Trials**

   A. Ratings of Perceived Urgency

ISI

ISI	Mean	SEM
0 ms	4.20	.09
500 ms	3.68	.08

Intensity

Intensity	Mean	SEM
12.0	1.78	0.05
23.5	6.09	0.07

Pattern

Pattern	Mean	SEM
Back	3.75	0.13
Front	4.13	0.13
Left	3.98	0.12
Right	3.89	0.13

ISI x Intensity

ISI	Intensity	Mean	SEM
0	12.0	1.78	.08
	23.5	6.62	.10
500	12.0	1.79	.07
	23.5	5.56	.10

Intensity x Pattern

Intensity	Pattern	Mean	SEM
12.0	Back	1.47	.10
	Front	1.85	.11
	Left	1.78	.10
	Right	2.03	.10
23.5	Back	6.02	.14
	Front	6.43	.14
	Left	6.16	.13
	Right	5.75	.17

B. Percent Detected

ISI

ISI	Mean	SEM
0 ms	84.6	1.11
500 ms	87.1	1.03

Intensity

Intensity	Mean	SEM
12.0	75.4	1.33
23.5	96.2	0.59

Pattern

Pattern	Mean	SEM
Back	81.5	1.69
Front	88.1	1.41
Left	87.7	1.43
Right	86.2	1.50

ISI x Intensity

ISI	Intensity	Mean	SEM
0	12.0	72.5	1.94
	23.5	96.6	0.79
500	12.0	78.4	1.80
	23.5	95.8	0.87

Intensity x Pattern

Intensity	Pattern	Mean	SEM
12.0	Back	65.5	2.93
	Front	77.3	2.58
	Left	78.3	2.55
	Right	80.7	2.43
23.5	Back	97.4	.099
	Front	98.9	.066
	Left	97.0	1.05
	Right	91.7	1.70

C. Overall Percent Correct

Intensity

Intensity	Mean	SEM
12.0	55.4	1.53
23.5	90.4	0.91

Pattern

Pattern	Mean	SEM
Back	68.1	2.03
Front	69.5	2.01
Left	78.4	1.79
Right	75.6	1.87

Intensity x Pattern

Intensity	Pattern	Mean	SEM
12.0	Back	43.2	3.05
	Front	46.6	3.08
	Left	64.6	2.95
	Right	67.1	2.90
23.5	Back	92.8	1.59
	Front	92.4	1.64
	Left	92.1	1.66
	Right	84.1	2.26

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